

Mark A. Cochrane

Tropical Fire Ecology

Climate Change, Land Use, and Ecosystem Dynamics

 Springer

Published in association with
Praxis Publishing
Chichester, UK

PRAXIS 

Contents

Preface	xvii
List of figures	xxi
List of tables	xxvii
List of abbreviations and acronyms	xxix
List of contributors	xxxiii
1 Fire in the tropics	1
1.1 Introduction	1
1.2 Tropical wildfires: situation and impacts	2
1.2.1 Overview	2
1.2.2 Economic impacts	4
1.2.3 Health issues	5
1.2.4 Environmental impacts	7
1.3 Case studies of tropical fires: Mexico and Brazil	10
1.3.1 Mexico	10
1.3.2 Brazil	14
1.4 Implications	17
1.5 Acknowledgments	18
1.6 References	18
2 Fire and fire ecology: Concepts and principles	25
2.1 Fire and combustion	25
2.2 Heat transfer	28
2.2.1 Conduction	28
2.2.2 Convection	29
2.2.3 Radiation	29

2.3	Fuels	31
2.3.1	Fuel composition	31
2.3.2	Fuel loading and arrangement	31
2.3.3	Fuel moisture	33
2.3.4	Total fuels	33
2.3.5	Live fuels	33
2.3.6	Dead fuels	37
2.3.7	Moisture exchange	37
2.3.8	Fuel continuity	38
2.4	Oxygen	39
2.5	Wildland fire	39
2.5.1	Fire types	40
2.5.2	Fire characteristics	41
2.6	Fire ecology	49
2.6.1	Fire regimes	49
2.6.2	Fire regime characteristics	50
2.6.3	Fire regime classification	51
2.6.4	The action of fire in ecosystems	53
2.6.5	Tropical fire ecology	55
2.7	Acknowledgments	55
2.8	References	55
PART I	Global overview of fire in the tropics	63
3	Overview: Global fire regime conditions, threats, and opportunities for fire management in the tropics	65
3.1	Abstract	65
3.2	Introduction	66
3.3	Assessing the World's fire regimes.	67
3.4	Fire regime types.	68
3.5	The state of the world's tropical fire regimes.	69
3.6	Causes of changing fire regimes in the tropics	72
3.6.1	Climate change	72
3.6.2	Agriculture and livestock ranching	73
3.6.3	Rural and urban development	75
3.6.4	Energy production	75
3.6.5	Fire exclusion and suppression	75
3.6.6	Invasive species	76
3.6.7	Plantations	76
3.6.8	Arson	76
3.7	Interactions	77
3.8	Prescribed burning for ecological benefit	77
3.9	Integrated fire management	77
3.10	Conclusions	79
3.11	References	80

PART II	Fire in the Australian tropics	85
4	Fire-driven land cover change in Australia and W.D. Jackson's theory of the fire ecology of southwest Tasmania	87
4.1	Abstract	87
4.2	Introduction	88
4.3	The ecology of southwest Tasmania	89
4.3.1	Development of a theory	89
4.3.2	Ecological Drift model	89
4.3.3	Evidence and alternative perspectives	93
4.4	The Ecological Drift model and quantifying fire frequency	94
4.4.1	Methods of quantifying fire frequency	94
4.4.2	Fire frequency in Victorian montane forests	95
4.4.3	Stand age and fire risk	96
4.4.4	Landscape effects on fire frequency	96
4.5	Fire frequency, edaphic feedbacks, and Aboriginal landscape burning in Australian tropical savannas	98
4.5.1	Aboriginal fire regimes: evidence from northern Australia savannas	98
4.5.2	Cessation of Aboriginal burning and the grass–fire cycle	99
4.5.3	Edaphic “inertia” of monsoon rainforest–savanna boundaries	99
4.5.4	Monsoon rainforest boundary dynamics	101
4.5.5	Monsoon rainforests and fire frequency	102
4.6	<i>Acacia aneura</i> shrublands in a <i>Triodia</i> grassland mosaic in central Australia	102
4.7	Ecological drift, changing fire regimes, and fire feedbacks	103
4.8	Conclusion	104
4.9	References	106
5	Fires in Australia's tropical savannas: Interactions with biodiversity, global warming, and exotic biota	113
5.1	Abstract	113
5.2	Introduction	113
5.2.1	The region	114
5.2.2	Fires in the region	117
5.3	Fire behavior, fire weather	118
5.4	Fire regimes	120
5.5	Relationships between fire, woody plants, and grasses	122
5.6	Fire, global warming, and greenhouse gases	124
5.6.1	Predicted changes in climate	124
5.6.2	Management of emissions	125
5.7	Biodiversity and fire regimes	126
5.7.1	Biodiversity, fire, and grazing regimes	126
5.7.2	Biodiversity conservation in reserves	129

5.8	Protection of human life and property	131
5.9	Discussion and conclusions	132
5.10	Acknowledgments	133
5.11	References	133
6	Aboriginal fire use in Australian tropical savannas: Ecological effects and management lessons	143
6.1	Abstract	143
6.2	Introduction	143
6.3	Stereotypes of seasonality and spatiality	147
6.4	Aboriginal uses for fire: hunting, vegetation management, and cleaning country	148
6.4.1	Fire for hunting	148
6.4.2	Domiculture: management of plant resources	151
6.4.3	Vegetation management: facilitating life in a tall-grass savanna	153
6.4.4	A landscape management system	153
6.5	European settlement and fire regimes	154
6.5.1	Ecological impact of wildfire regimes	154
6.5.2	Contemporary Aboriginal fire management	156
6.6	Conclusion	161
6.7	References	161
PART III	Fire in the African tropics	169
7	Fire ecology and fire politics in Mali and Madagascar	171
7.1	Abstract	171
7.2	Introduction	172
7.3	Biophysical context	174
7.3.1	Mali and West Africa	174
7.3.2	Madagascar	176
7.4	Prehistory	177
7.4.1	Generalities on prehistoric African fire and issues of vegetation “origin”	177
7.4.2	West African anthropogenic fire history	180
7.4.3	Madagascar	181
7.5	Contemporary fire regimes and impacts	182
7.5.1	Mali	182
7.5.2	Madagascar	185
7.6	Humans and fire in landscape management	187
7.6.1	Why do Africans burn the land?	187
7.6.2	Seasonal mosaic burning in Mali	189
7.6.3	The culture of fire use in Madagascar	196

7.7	Estimating fire impacts	201
7.7.1	Climate and hydrology.	202
7.7.2	Land cover conversion and vegetation change	203
7.7.3	Fragmentation and connectivity	204
7.7.4	Atmospheric and health effects of emissions	205
7.8	Fire politics	206
7.8.1	Early fire policies	206
7.8.2	Fire as a necessary evil: a late colonial softening	208
7.8.3	Post-colonial approaches: strong words, weak enforcement	208
7.8.4	From drought to revenue: fire in 1980s' Mali	209
7.8.5	Biodiversity hotspot: fire in 1980s'–1990s' Madagascar	211
7.8.6	The 1990s' community devolution movement	212
7.8.7	Today	212
7.8.8	Lessons	213
7.9	Conclusion	214
7.10	References	215
8	Climate change and wildland fires in Mozambique.	227
8.1	Abstract	227
8.2	Introduction	228
8.3	Climate, fire, and livelihood linkages	229
8.4	Climate conditions: present and future projections	230
8.4.1	Current climatic conditions	231
8.4.2	Future climate change projections	233
8.5	Current fire regimes in Mozambique today	234
8.5.1	Fire distribution and frequency	235
8.5.2	Fire seasonality	236
8.6	Underlying causes of wildland fire	236
8.6.1	Ecological impacts of fire	237
8.6.2	Miombo woodland species	238
8.6.3	Ecological consequences of fire in the miombo woodland	242
8.7	Economic impacts of fire	244
8.8	Emissions from biomass burning	246
8.8.1	Emissions released directly from fires	247
8.8.2	Emissions from land use change and forestry	247
8.9	Policy framework and institutional arrangements	248
8.9.1	Historical policy and institutional framework	248
8.9.2	Current policy and institutional framework	249
8.10	Conclusions	251
8.11	Acknowledgment	254
8.12	References	255

PART IV Fire in the Asian tropics	261
9 Tropical peatland fires in Southeast Asia	263
9.1 Abstract	263
9.2 Introduction	264
9.3 The tropical peatlands of Southeast Asia	265
9.4 Fire history and the causes of fire	266
9.5 Land use change as the driver of contemporary peatland fires	269
9.6 Causes of fire; the blame game	270
9.6.1 Role of fire in recent deforestation of tropical peatlands in Borneo	272
9.7 Ecological changes	276
9.7.1 From fire to flood	276
9.7.2 Carbon emissions and fire behavior	279
9.7.3 Tropical peatlands under a changing climate	281
9.8 Future prospects	282
9.9 References	283
10 Fire ecology and management of seasonal evergreen forests in mainland Southeast Asia	289
10.1 Abstract	289
10.2 Introduction	289
10.3 Study area	292
10.4 Fire in seasonal evergreen forest	294
10.5 Why do seasonal evergreen forests burn?	298
10.6 Effect of fire on seasonal evergreen forest	301
10.7 Summary and implications	305
10.8 References	306
11 Fire behavior and fire effects across the forest landscape of continental Southeast Asia	311
11.1 Abstract	311
11.2 Introduction	312
11.3 Causes of fire	314
11.3.1 Climate	314
11.3.2 Fuels	315
11.3.3 Ignition	316
11.4 Fire behavior	316
11.5 Fire severity	320
11.5.1 Fire effects on individual trees	320
11.5.2 Fire effects at the stand scale	322
11.5.3 Fire and tree species abundance	323
11.6 Fire regimes	326
11.7 Fire, landscapes, and land use	328
11.8 Fire and climate	329

11.9	Issues for fire management	330
11.10	References	331
12	Forest fire regimes and their ecological effects in seasonally dry tropical ecosystems in the Western Ghats, India	335
12.1	Abstract	335
12.2	Introduction	336
12.3	Humans and fire in the Western Ghats	336
12.3.1	Indigenous communities and fires	337
12.3.2	Agricultural fires in the Western Ghats	337
12.3.3	Fire and forestry	337
12.4	Link between fire regimes and field studies	337
12.5	Background	338
12.5.1	Spatial parameters of fire regimes	338
12.5.2	Vegetation types and forest fires in the Nilgiri landscape	339
12.6	Methods	340
12.6.1	Vegetation map	340
12.6.2	Delineating forest fires in the Nilgiri landscape	340
12.6.3	Forest structure, diversity, fuel loads, and fire frequency	341
12.7	Results	342
12.7.1	Spatial and temporal characteristics of fires in the Nilgiri landscape	342
12.7.2	Fuels, vegetation characteristics, and forest fires	343
12.8	Discussion	349
12.8.1	Climate change and forest fires	350
12.8.2	Forest fires and conservation	350
12.9	Conclusions	351
12.10	Acknowledgments	351
12.11	References	351
13	Fire and land use effects on biodiversity in the southern Sumatran wetlands	355
13.1	Abstract	355
13.2	Introduction	356
13.3	Methods	358
13.3.1	Land cover classification	358
13.3.2	Socio-economic surveys	359
13.3.3	Field ecological surveys	359
13.3.4	Distance and access	359
13.3.5	Fire patterns	359
13.3.6	Vegetation structure and links to environmental/disturbance variables	360
13.3.7	Woody species diversity and composition	360
13.4	Fire history	361
13.5	Land use history	363

13.6	Driving forces behind the fires	365
13.7	Biodiversity impacts	367
13.7.1	Landscape level	367
13.7.2	Woody species diversity and composition at the patch level	368
13.7.3	Vegetation structure at the patch level	374
13.7.4	Further fire susceptibility and regeneration potential	375
13.8	Discussion	377
13.8.1	Fire management issues and options for the wetlands of southern Sumatra	379
13.9	Acknowledgments	381
13.10	References	382

PART V Fire in the South American tropics 387

14	Fire, land use, land cover dynamics, and climate change in the Brazilian Amazon	389
14.1	Abstract	389
14.2	Introduction	390
14.3	Fire as a tool	391
14.4	Fire and land use	392
14.4.1	Shifting cultivation	392
14.4.2	Cattle ranching	392
14.4.3	Industrial agriculture	393
14.4.4	Logging	393
14.4.5	Fire and landscapes	395
14.5	Fire behavior	398
14.6	Fire severity	400
14.7	Ecosystem effects	402
14.8	Fire and climate	406
14.8.1	Climate, weather anomalies, and climate change effects	406
14.8.2	Land cover change and climate	408
14.8.3	Fire and climate	408
14.9	Fire modeling	409
14.9.1	Fire susceptibility	409
14.9.2	Mechanistic model of fire susceptibility	410
14.9.3	Fuels	413
14.10	Conclusions	415
14.10.1	Rehabilitating fire-impacted forests	417
14.11	Acknowledgments	418
14.12	References	418

15 Fires in the cerrado, the Brazilian savanna	427
15.1 Abstract	427
15.2 Introduction	427
15.3 Fire history and fire frequency	428
15.4 Cerrado fires	430
15.5 Herbaceous-layer vegetation	433
15.6 Woody-layer vegetation	437
15.7 Water use and carbon flux	442
15.8 Final considerations	443
15.9 References	444
16 The role of fire in the vegetation dynamics of upland savannas of the Venezuelan Guayana	451
16.1 Abstract	451
16.2 Introduction	452
16.3 Causes and use of fire	453
16.4 Study site	454
16.5 Experimental design	458
16.6 Fire behavior	460
16.7 Effect of fire on savanna plant cover and species composition	465
16.7.1 Plant species composition and abundance	466
16.7.2 Effect of fire on plant species composition and abundance	469
16.8 Effect of fire on savanna biomass	470
16.8.1 Biomass dynamics in unburned savanna plots	471
16.8.2 Biomass recovery of burned savanna plots	472
16.8.3 Biomass recovery and fire frequency	473
16.9 Conclusions: Options for fire management in Canaima National Park	473
16.10 Acknowledgments	475
16.11 References	476
17 Pattern and process: Fire-initiated grass invasion at Amazon transitional forest edges	481
17.1 Abstract	481
17.2 Introduction	482
17.3 Methods: increasing fire frequency at a forest–pasture edge	483
17.4 Results: fire promotes grass invasion	484
17.5 Potential mechanisms of fire-initiated vegetation transitions	487
17.5.1 Competition-based mechanisms	487
17.5.2 Demographic mechanisms	491
17.5.3 Grass–fire cycle	494
17.6 Conclusions	495
17.7 Acknowledgments	496
17.8 References	497

PART VI	Fire in the Central American tropics	503
18	Fire in the páramo ecosystems of Central and South America	505
18.1	Abstract	505
18.2	Introduction	506
18.3	The páramos of Central and South America	506
18.4	Causes of páramo fires	510
18.5	The “naturalness”, fire dependency, and conservation value of neotropical páramos	512
18.6	Fire behavior	515
18.7	Fire severity and post-fire vegetation development	516
18.8	Fire frequency	520
18.9	Charcoal and pollen evidence of long-term fire history	522
18.9.1	Records from Costa Rica	522
18.9.2	Records from Ecuador and northern Peru	524
18.10	Issues for fire management	527
18.11	Acknowledgments	531
18.12	References	531
PART VII	Pan-tropical fire	541
19	The consequences of fire for the fauna of humid tropical forests	543
19.1	Abstract	543
19.2	Introduction	543
19.3	Faunal mortality and temporal responses to fire	544
19.4	Sub-lethal effects	546
19.5	Fire severity and recurrent fires	546
19.6	Spatial scale of effects	547
19.7	Fires and other threats to biodiversity	548
19.8	Synergistic effects of fire	548
19.9	Geographical variance in faunal responses to fire	549
19.10	Fire and the arthropod litter fauna	550
19.11	Conclusion and research priorities	551
19.12	References	553
20	Fire in tropical pine ecosystems	557
20.1	Abstract	557
20.2	Introduction	558
20.3	Fire and life history characteristics and adaptations of tropical pines	561
20.4	Ecosystem characteristics	569
20.5	Fire regimes	570
20.6	Pine stand structure and stand dynamics	574
20.7	Ecosystem dynamics	579

20.8	Causes of fire	582
20.9	Fire behavior and severity	585
20.10	Fire, land use, and landscapes	587
20.11	Fire, pines, and climate change	589
20.12	Issues for fire management	591
20.13	Regional example: <i>Pinus hartwegii</i> forests in Mesoamerica	592
20.13.1	Background	592
20.13.2	Fire regime and vegetation dynamics	593
20.13.3	Fire behavior and severity	593
20.13.4	Understory species response to fire	595
20.13.5	Wildlife	596
20.13.6	Soils, hydrology, and air quality	596
20.13.7	Landscape value	597
20.13.8	Other project studies	597
20.13.9	Integrated fire management	597
20.14	Conclusion	598
20.15	References	599
21	Changing fire regimes in tropical montane cloud forests: a global synthesis	607
21.1	Abstract	607
21.2	Introduction	607
21.3	MCFs: characteristics, distribution, and disturbance dynamics	609
21.4	Paleoecological evidence for historical fire regimes in MCFs	610
21.5	Modern evidence for changing fire regimes in MCFs	614
21.6	Case study: modern patterns of fire activity in MCFs of south-eastern Mexico	617
21.7	Conclusions	621
21.8	Acknowledgements	622
21.9	References	622
Index	627